



US007932805B2

(12) **United States Patent**  
**Darr et al.**

(10) **Patent No.:** **US 7,932,805 B2**  
(45) **Date of Patent:** **Apr. 26, 2011**

(54) **FUSE WITH FUSE STATE INDICATOR**

(75) Inventors: **Matthew R. Darr**, Godfrey, IL (US);  
**Jaime A. Torrez**, O'Fallon, MO (US);  
**Anthony C. Ban**, Foley, MO (US);  
**Robert S. Douglass**, Wildwood, MO  
(US); **John M. Ackermann**, Belleville,  
IL (US)

4,929,090 A 5/1990 Grahm  
5,111,177 A 5/1992 Krueger et al.  
5,738,442 A 4/1998 Paron et al.  
5,776,371 A 7/1998 Parker  
5,821,849 A 10/1998 Dietsch et al.  
5,841,337 A 11/1998 Douglass  
5,936,508 A 8/1999 Parker

(Continued)

(73) Assignee: **Cooper Technologies Company**,  
Houston, TX (US)

**FOREIGN PATENT DOCUMENTS**

DE 711966 C 10/1941

(Continued)

(\* ) Notice: Subject to any disclaimer, the term of this  
patent is extended or adjusted under 35  
U.S.C. 154(b) by 0 days.

**OTHER PUBLICATIONS**

International Search Report of PCT/US2008/081347; Jan. 20, 2009;  
7 pages.

(21) Appl. No.: **12/868,298**

(Continued)

(22) Filed: **Aug. 25, 2010**

(65) **Prior Publication Data**

US 2010/0328019 A1 Dec. 30, 2010

*Primary Examiner* — Anatoly Vortman

(74) *Attorney, Agent, or Firm* — Armstrong Teasdale LLP

(51) **Int. Cl.**

**H01H 85/30** (2006.01)

(52) **U.S. Cl.** ..... **337/243**; 337/241; 337/206; 337/265;  
116/206; 116/207; 324/507; 324/550; 340/638

(58) **Field of Classification Search** ..... 337/241,  
337/242, 245, 265, 206, 243, 248–252, 187;  
116/206, 207; 324/507, 550; 439/491; 340/638,  
340/639

See application file for complete search history.

(57)

**ABSTRACT**

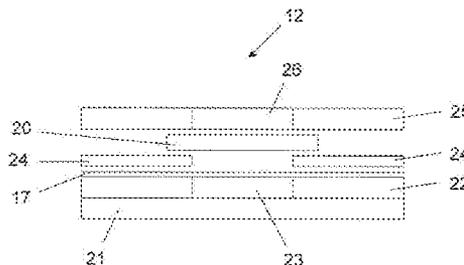
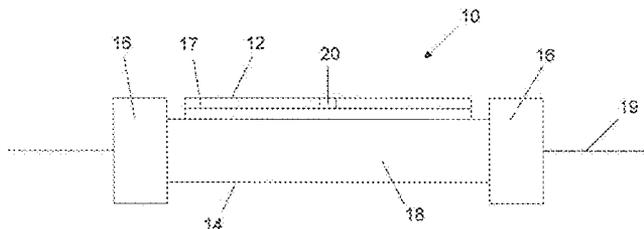
A fuse includes a fuse state indicator on the exterior surface of the fuse body. The fuse state indicator includes an electrically conductive element electrically connected to and extending between the terminal elements. A temperature sensitive element proximate and in thermal contact with the electrically conductive element includes material capable of changing color when heated to a predetermined transition temperature to form a mark on the temperature sensitive element. The fuse state indicator forms a first mark on the temperature sensitive element when heat from the electrically conductive element transfers to the temperature sensitive element in response to a first overcurrent condition, and forms a second mark, distinct from the first mark, on the temperature sensitive element when heat from the electrically conductive element transfers to the temperature sensitive element in response to a second overcurrent condition distinct from the first overcurrent condition.

(56) **References Cited**

**U.S. PATENT DOCUMENTS**

1,591,029 A 7/1926 Feldkamp  
2,945,305 A 7/1960 Strickler  
4,070,912 A 1/1978 McNaughtan et al.  
4,308,516 A 12/1981 Shimada et al.  
4,339,207 A 7/1982 Hof et al.  
4,468,137 A 8/1984 Hilsum et al.  
4,538,926 A 9/1985 Chretien

**30 Claims, 11 Drawing Sheets**



U.S. PATENT DOCUMENTS

5,994,993	A	11/1999	Castonguay, Jr. et al.	
6,114,941	A	9/2000	Scott	
6,292,087	B1	9/2001	Castonguay, Jr. et al.	
6,373,370	B1 *	4/2002	Darr et al. ....	337/243
6,456,189	B1	9/2002	Mosesian et al.	
6,809,627	B2	10/2004	Castonguay, Jr. et al.	
6,836,206	B2 *	12/2004	Lee .....	337/243
6,859,131	B2 *	2/2005	Stanek et al. ....	337/206
7,369,030	B2 *	5/2008	Darr .....	337/243
7,405,646	B2 *	7/2008	Kennedy et al. ....	337/243
7,636,028	B2 *	12/2009	Rodseth et al. ....	337/243
2004/0000983	A1	1/2004	Kennedy et al.	
2005/0062578	A1	3/2005	Ackermann	
2006/0040546	A1	2/2006	Werthman et al.	
2008/0232427	A1	9/2008	Leute et al.	
2009/0108983	A1	4/2009	Darr et al.	

FOREIGN PATENT DOCUMENTS

DE	8215732	5/1984
DE	8514462	2/1987
GB	517905 A	2/1940
GB	575936 A	3/1946
GB	594736	11/1947
GB	2135874	9/1984
JP	52141281	11/1977
WO	WO 89/04532	5/1989
WO	9930337 A2	6/1999

OTHER PUBLICATIONS

International Search Report and Written Opinion of PCT/US2008/081347; Mar. 16, 2009; 17 pages.

International Search report and Written Opinion of PCT/US2008/080441; Feb. 16, 2009; 12 pages.

\* cited by examiner

FIG. 1

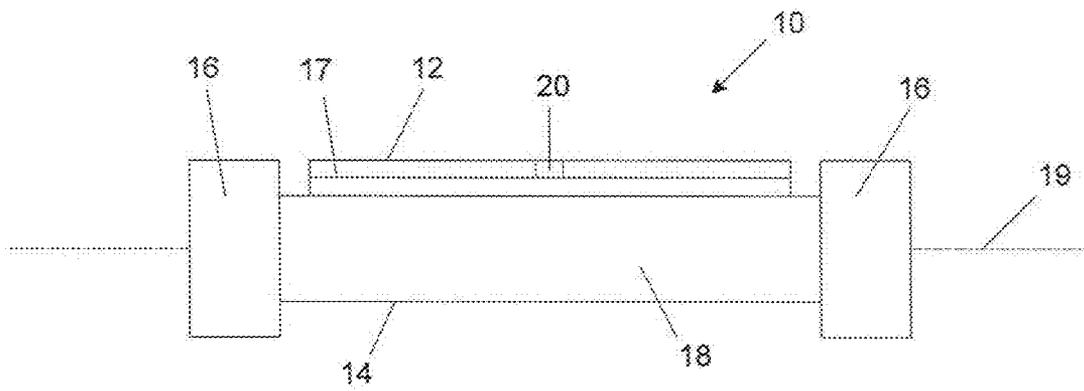


FIG. 2

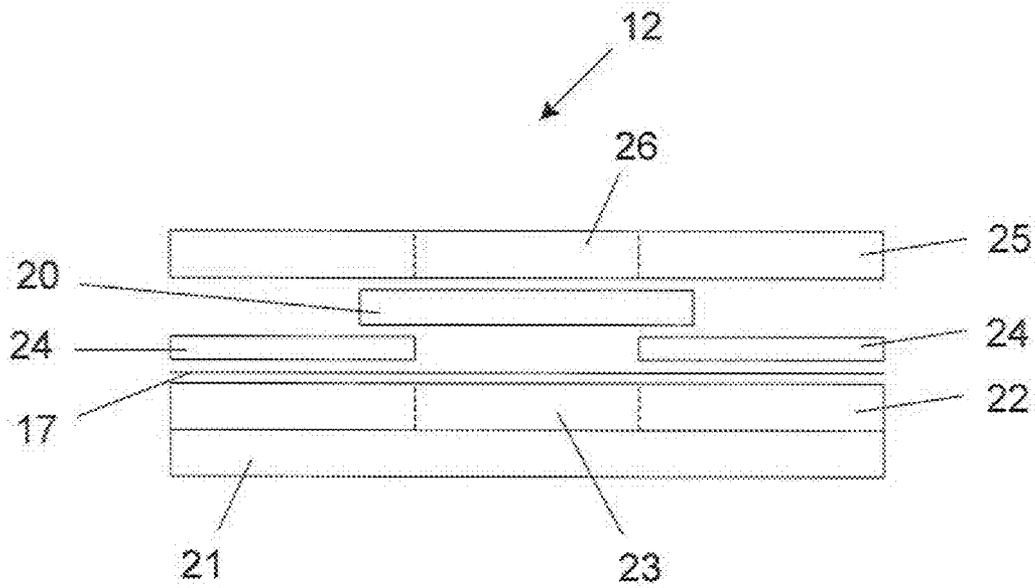


FIG. 3A

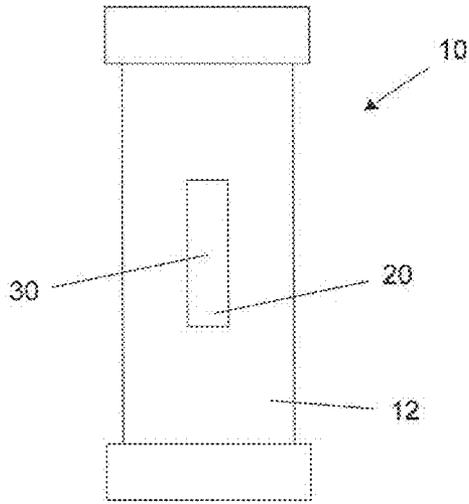


FIG. 3B

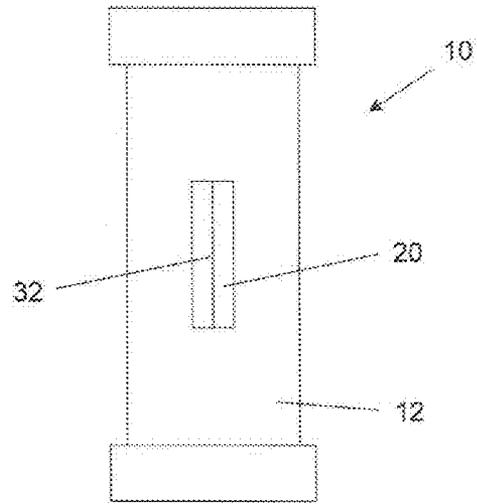


FIG. 3C

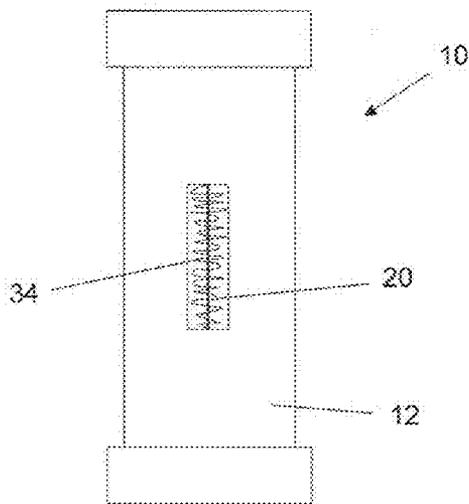


FIG. 3D

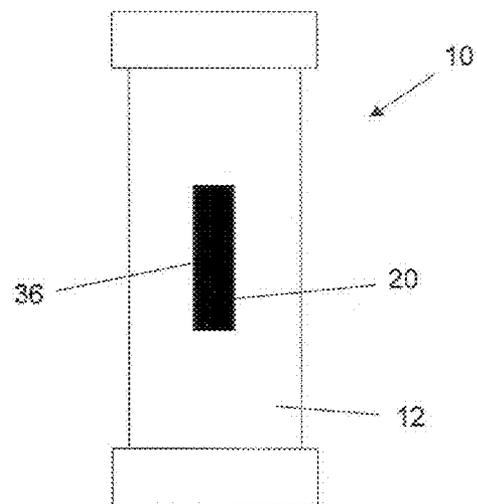


FIG. 4A

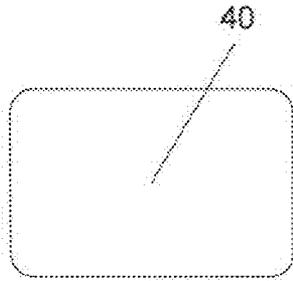


FIG. 4B

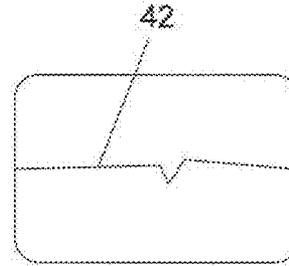


FIG. 4C

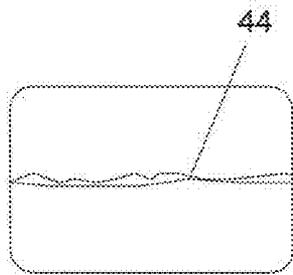


FIG. 4D

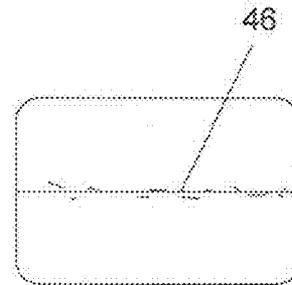


FIG. 4E

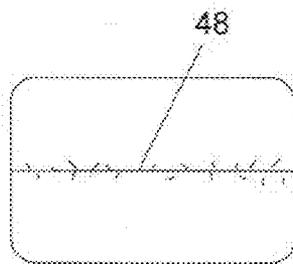


FIG. 4F

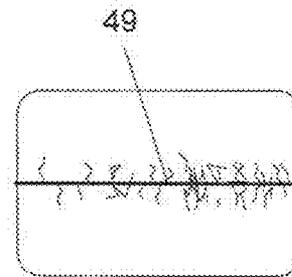


FIG. 5

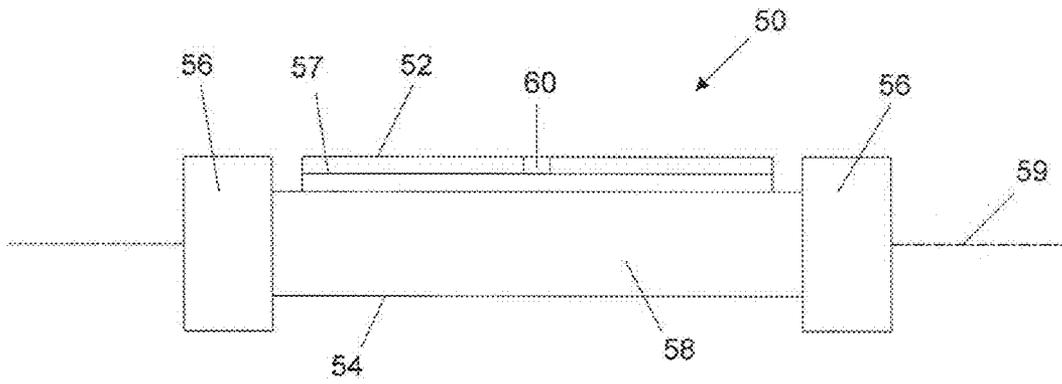


FIG. 6

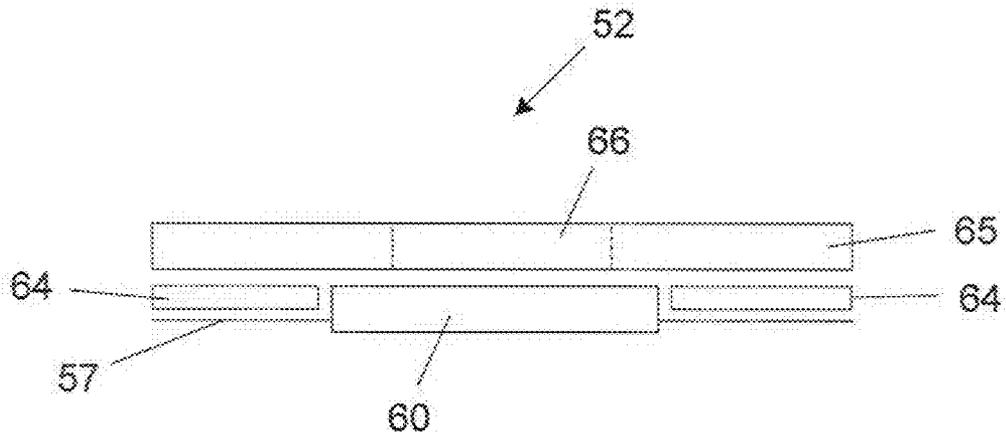


FIG. 7A

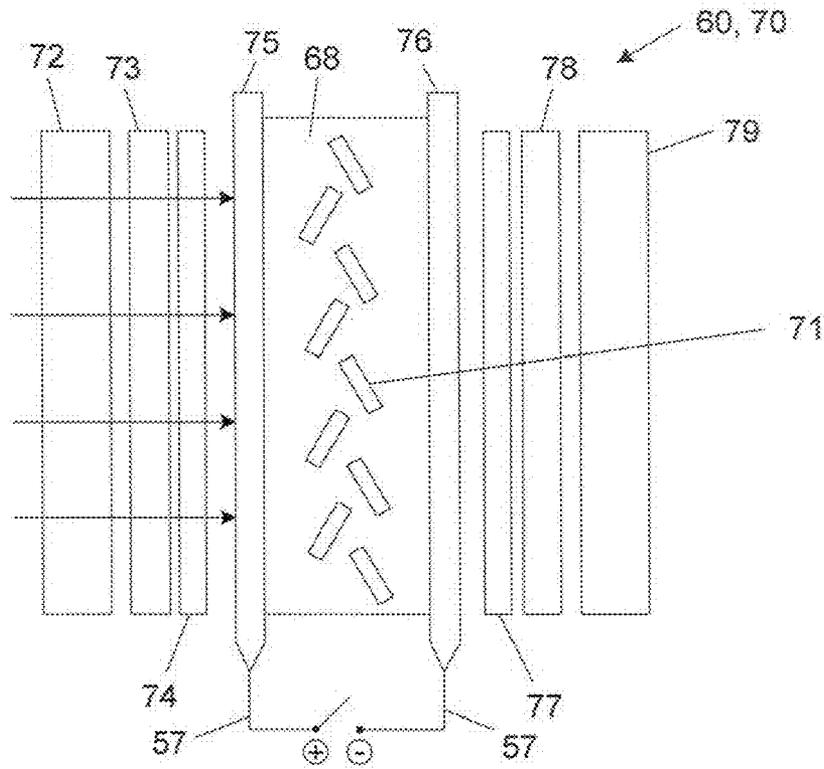


FIG. 7B

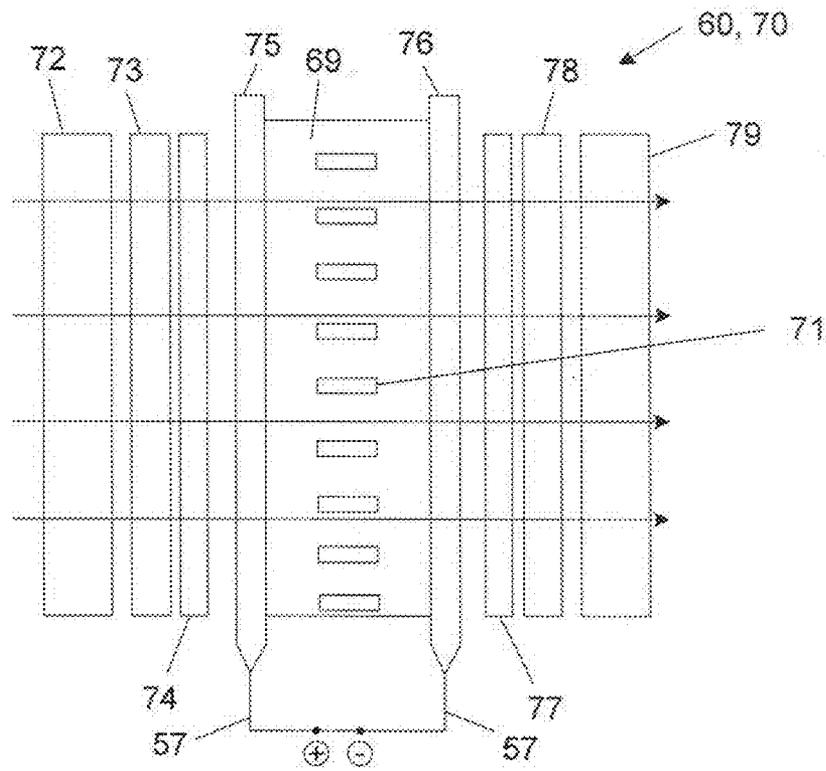


FIG. 8A

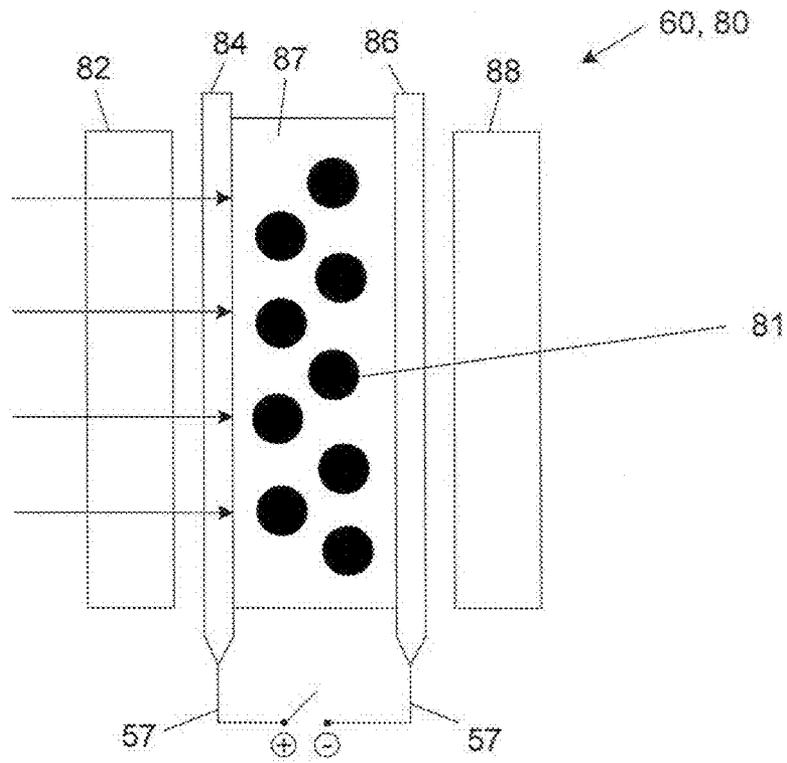


FIG. 8B

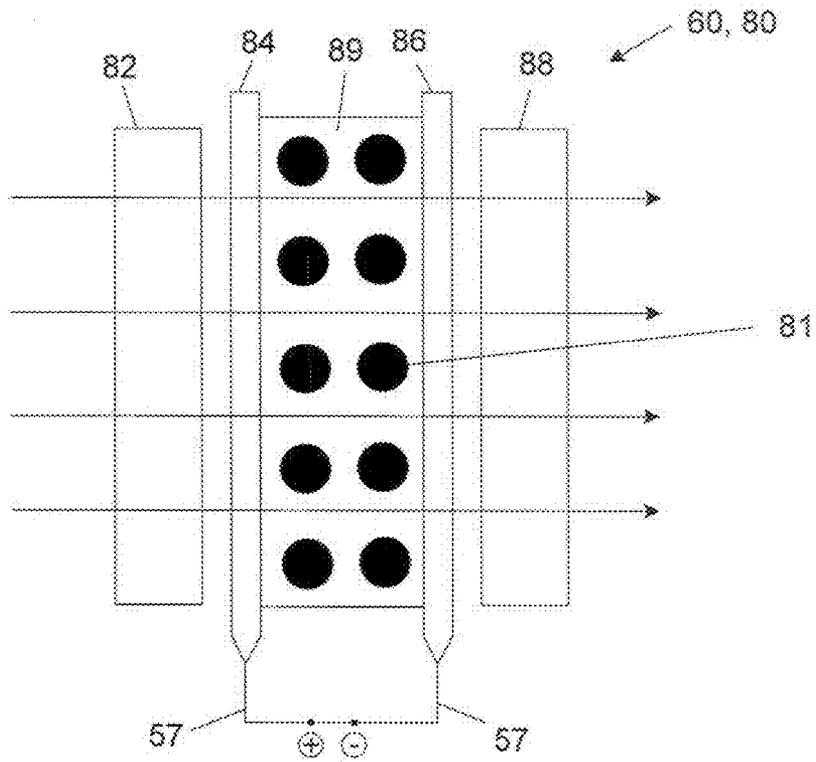


FIG. 9

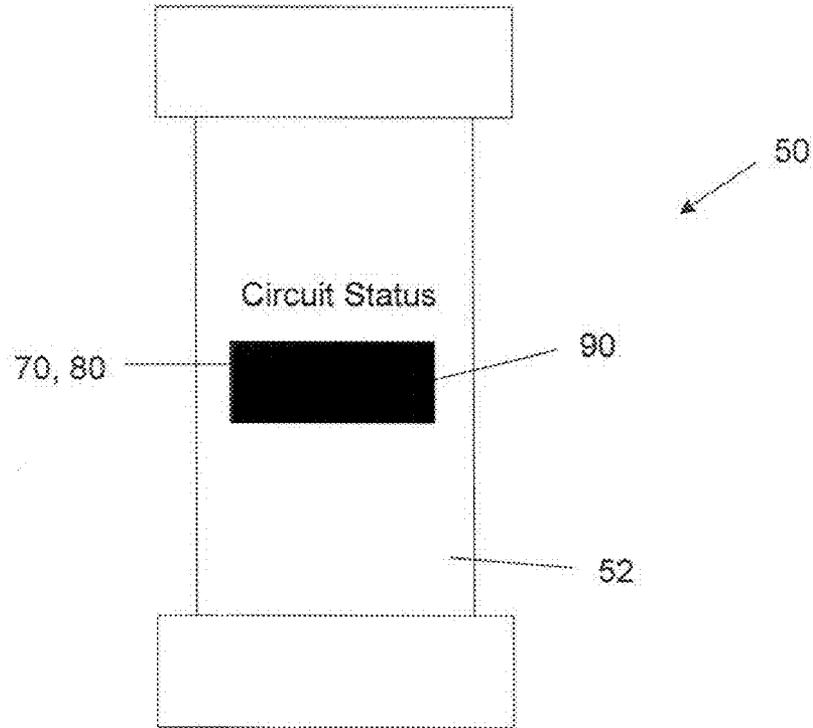


FIG. 10

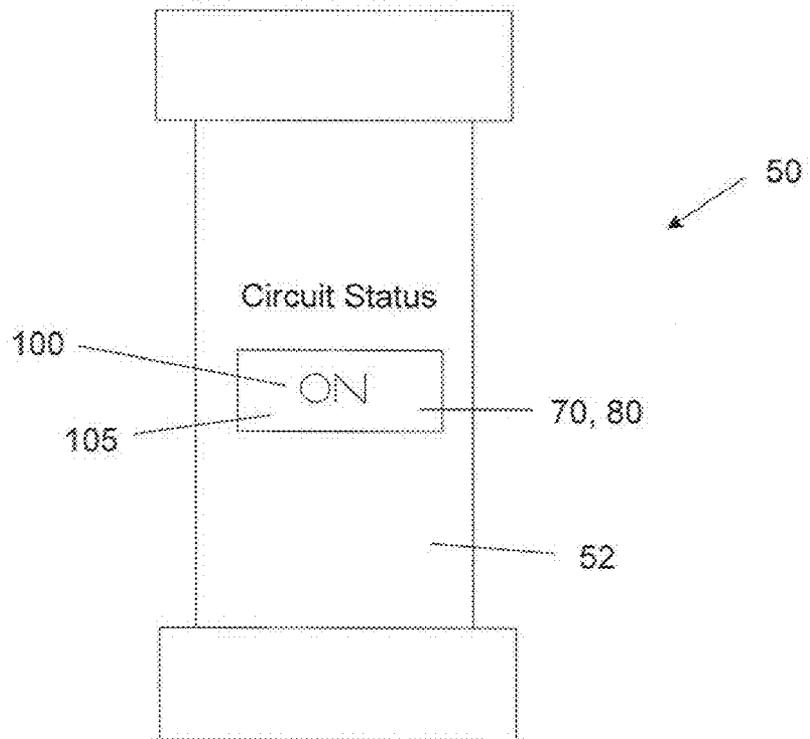


FIG. 11A

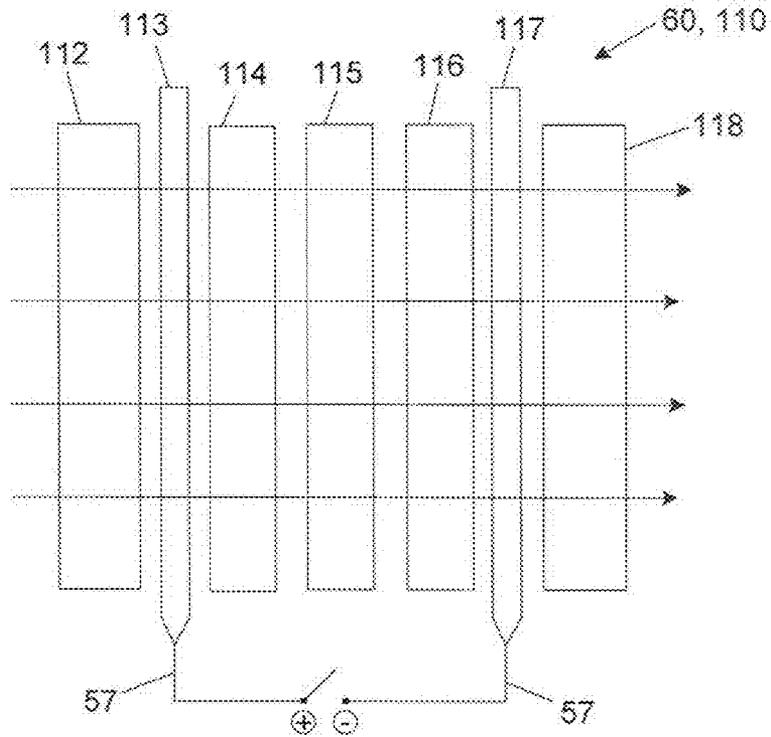


FIG. 11B

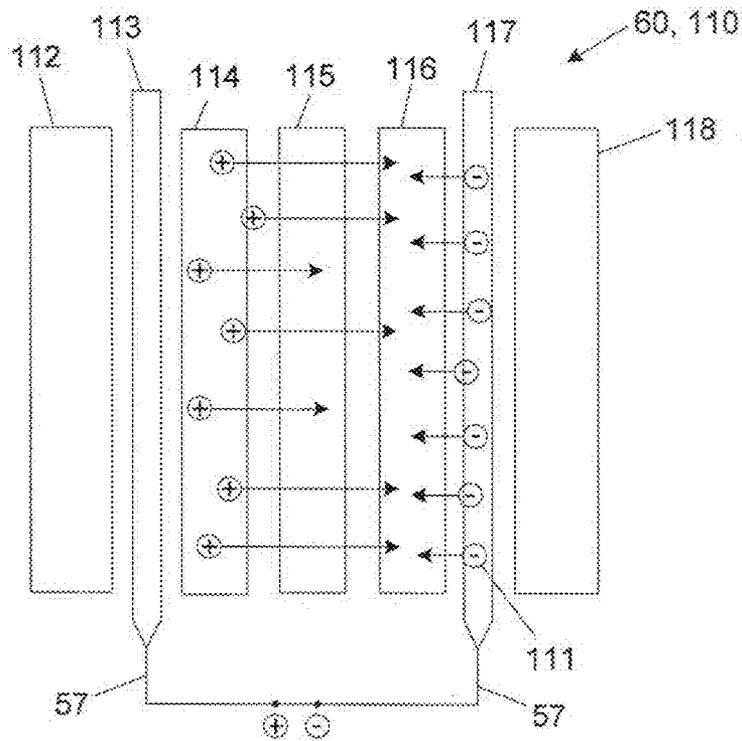


FIG. 12

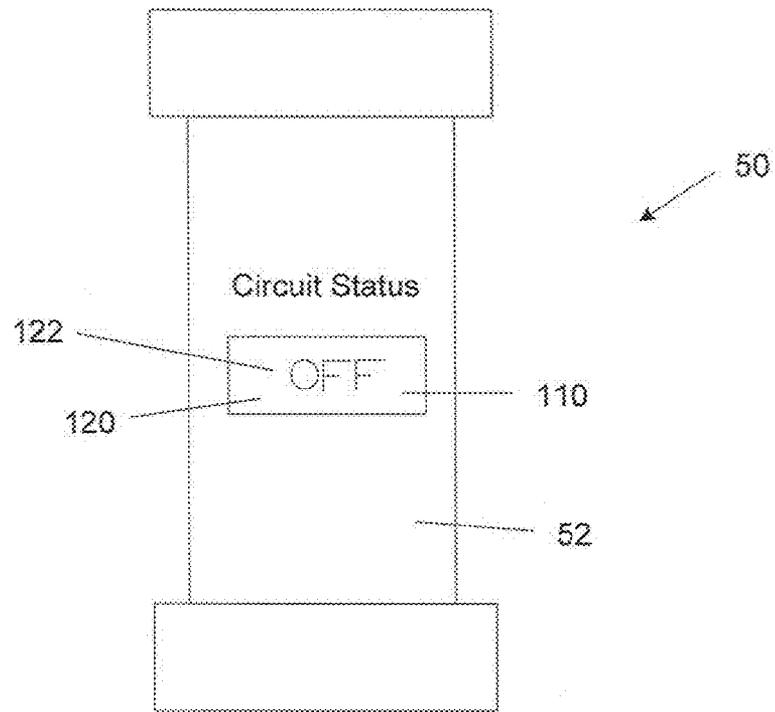
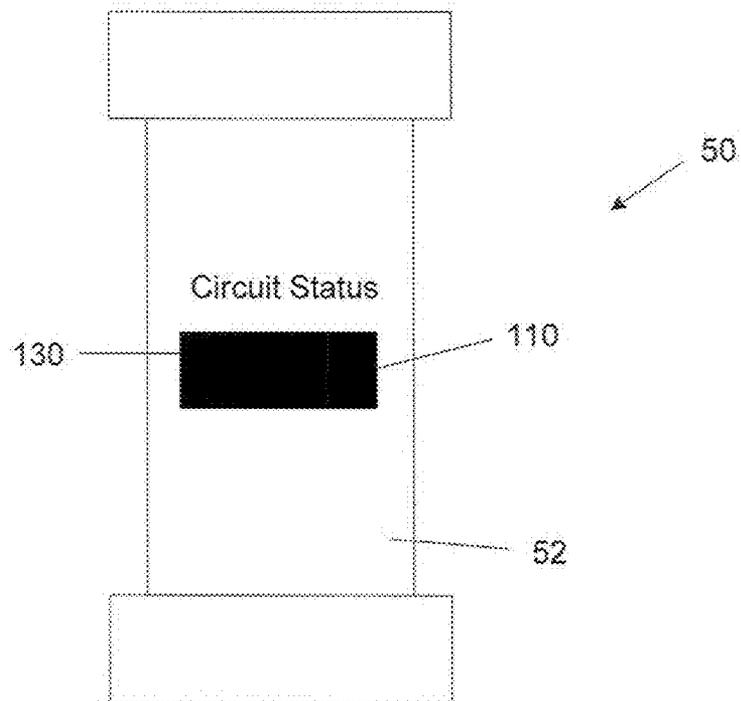


FIG. 13



## FUSE WITH FUSE STATE INDICATOR

## CROSS REFERENCE TO RELATED APPLICATIONS

This application claims priority to U.S. patent application Ser. No. 11/939,981, filed Nov. 14, 2007 and issued as U.S. Pat. No. 7,812,704, the entirety of which is incorporated herein by reference.

## BACKGROUND OF THE INVENTION

This invention relates generally to fuses and, more particularly, to fuses with a fuse state indicator.

## BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and other features and aspects of the invention will be best understood with reference to the following description of certain exemplary embodiments of the invention, when read in conjunction with the accompanying drawings, wherein:

FIG. 1 is a plan view of a fuse comprising a fuse state indicator that responds to temperature in accordance with an exemplary embodiment;

FIG. 2 is a cross sectional view of a fuse state indicator in accordance with an exemplary embodiment;

FIG. 3A is a top view of a fuse comprising a fuse state indicator displaying a good fuse state in accordance with an exemplary embodiment;

FIG. 3B is a top view of a fuse comprising a fuse state indicator displaying an overload open fuse state in accordance with an exemplary embodiment;

FIG. 3C is a top view of a fuse comprising a fuse state indicator displaying a short circuit open fuse state in accordance with an exemplary embodiment;

FIG. 3D is a top view of a fuse comprising a fuse state indicator displaying a thermal stress and/or open fuse state in accordance with an exemplary embodiment;

FIG. 4A is a photographic view of a temperature sensitive element displaying a good fuse state in accordance with an exemplary embodiment;

FIG. 4B is a photographic view of a temperature sensitive element displaying a 200% overload fuse state in accordance with an exemplary embodiment;

FIG. 4C is a photographic view of a temperature sensitive element displaying a 1200 A overload fuse state in accordance with an exemplary embodiment;

FIG. 4D is a photographic view of a temperature sensitive element displaying a 2400 A short circuit fuse state in accordance with an exemplary embodiment;

FIG. 4E is a photographic view of a temperature sensitive element displaying a 10 KA short circuit fuse state in accordance with an exemplary embodiment;

FIG. 4F is a photographic view of a temperature sensitive element displaying a 100 KA short circuit fuse state in accordance with an exemplary embodiment;

FIG. 5 is a plan view of a fuse comprising a fuse state indicator that responds to voltage in accordance with an exemplary embodiment;

FIG. 6 is a cross sectional view of a fuse state indicator in accordance with an exemplary embodiment;

FIG. 7A is a perspective view of a smart window showing the orientation of a plurality of polymer dispersed liquid crystals when there is no voltage flowing across the smart window in accordance with an exemplary embodiment;

FIG. 7B is a perspective view of a smart window showing the orientation of a plurality of polymer dispersed liquid crystals when there is voltage flowing across the smart window in accordance with an exemplary embodiment;

FIG. 8A is a perspective view of a smart window showing the orientation of a plurality of suspended particle devices when there is no voltage flowing across the smart window in accordance with an exemplary embodiment;

FIG. 8B is a perspective view of a smart window showing the orientation of a plurality of suspended particle devices when there is voltage flowing across the smart window in accordance with an exemplary embodiment;

FIG. 9 is a top view of a fuse comprising a fuse state indicator displaying an inoperable fuse state in accordance with an exemplary embodiment;

FIG. 10 is a top view of a fuse comprising a fuse state indicator displaying an operable fuse state in accordance with an exemplary embodiment;

FIG. 11A is a perspective view of a smart window showing the positioning of a plurality of ions when there is no voltage flowing across the smart window in accordance with an exemplary embodiment;

FIG. 11B is a perspective view of a smart window showing the positioning of a plurality of ions when there is voltage flowing across the smart window in accordance with an exemplary embodiment;

FIG. 12 is a top view of a fuse comprising a fuse state indicator displaying an inoperable fuse state in accordance with an exemplary embodiment; and

FIG. 13 is a top view of a fuse comprising a fuse state indicator displaying an operable fuse state in accordance with an exemplary embodiment.

## DETAILED DESCRIPTION OF THE INVENTION

FIG. 1 is a plan view of a fuse 10 comprising a fuse state indicator 12 that responds to temperature in accordance with an exemplary embodiment. The fuse 10 includes an insulative (i.e., nonconductive) fuse body 14 and conductive ferrules 16 attached thereto on either end thereof. The fuse state indicator 12 extends on an outer surface 18 of the fuse body 14 between the ferrules 16 and is electrically connected to the ferrules 16 by a wire 17. The fuse body 14 is elongated in the direction of a longitudinal axis 19 and is generally cylindrical in the illustrated embodiment. It is appreciated that the benefits of the instant invention may also apply to non-cylindrical fuses, including but not limited to rectangular fuses, in alternative embodiments. Further, it is understood that the Invention is applicable to a wide variety of fuses intended for a wide variety of applications and having a wide variety of fuse ratings. Therefore, the embodiments of the invention shown and described herein are for illustrative purposes only, and the invention is not intended to be restricted to a particular fuse type, class, or rating.

In an exemplary embodiment, the ferrules 16 are generally cylindrical and complementary in shape to the fuse body 14. It is, however, appreciated that the benefits of the instant invention may also apply to non-cylindrical ferrules, including but not limited to rectangular ferrules, in alternative embodiments.

The fuse state indicator 12 comprises at least one temperature sensitive element 20 capable of undergoing a visible change upon being subjected to a threshold temperature. The temperature sensitive element 20 is adapted to visibly indicate the state of fuse 10. The state of fuse 10 may be indicated as a good fuse, an overload open fuse, a short circuit open fuse, and/or thermal stress and/or open fuse. Other fuse states

3

and other descriptions for the fuse states may be used in alternative embodiments without departing from the scope and spirit of the exemplary embodiment. The temperature sensitive element 20 may be employed as part of the fuse state indicator 12 coupled to the outer surface 18 of the fuse 10 or the temperature sensitive element 20 may be employed independently. The temperature sensitive element 20 is coupled to the outer surface 18 of the fuse body 14 between the ferrules 16, but is not electrically connected to the ferrules 16 by the wire 17. The temperature sensitive element 20 is positioned on or in close proximity to the wire 17 so that it may detect the heat emanating from the wire 17. The heat is generated by the current passing through the wire 17 and is dependent upon the resistance of that wire 17. The wire 17 is designed so that it melts or becomes disconnected once a short circuit or a harmful overload condition occurs. In one embodiment, the wire 17 comprises a NiChrome alloy that melts above 1000° C. It should be understood that the wire may be constructed of other materials capable of melting, when exposed to a harmful overload condition, without departing from the scope and spirit of the exemplary embodiment.

FIG. 2 is a cross sectional view of a fuse state indicator 12 in accordance with an exemplary embodiment. In this embodiment, the fuse state indicator 12 comprises a clear laminate 21, a print ink 22, a wire 17, at least one foil 24 and a temperature sensitive element 20. The print ink 22 comprises an adhesive (not shown) positioned adjacent to the clear laminate 21, wherein the print ink 22 has a first window 23 defined therewithin. The wire 17 is electrically coupled to the ferrules 16 (FIG. 1) and passes longitudinally across the first window 23. The wire 17 may be positioned adjacent to the print ink 22. The at least one foil 24 may be coupled to the portion of the wire 17 that is not passing longitudinally across the first window 23. The temperature sensitive element 20 may be coupled to at least the portion of the wire 17 that passes longitudinally across the first window 23. The fuse state indicator 12 may further comprise a label 25 positioned adjacent to the temperature sensitive element 20, wherein the label 25 has a second window 26 defined therewithin. The second window 26 may be positioned above the temperature sensitive element 20 such that the temperature sensitive element 20 may be visible while viewing through the second window 26. In this exemplary embodiment, the temperature sensitive element 20 comprises thermographic paper.

The foil 24 is designed to protect an operator from exposure to excessive temperatures from the wire 17 while handling fuse 10. The foil 24 may comprise any material capable of insulating the heat, including, but not limited to, copper foil or any thick film, without departing from the scope and spirit of the exemplary embodiment.

FIGS. 3A-3D illustrate a top view of a fuse 10 comprising a fuse state indicator 12 displaying various fuse states in accordance with an exemplary embodiment. FIG. 3A is a top view of a fuse 10 comprising a fuse state indicator 12 displaying a good fuse state 30. The good fuse state 30 is indicated on the thermographic paper 20 as being entirely clear or having a faint wire line barely noticeable by an operator.

FIG. 3B is a top view of a fuse 10 comprising a fuse state indicator 12 displaying an overload open fuse state 32. The overload open fuse state 32 is indicated on the thermographic paper 20 as being a thin wire line.

FIG. 3C is a top view of a fuse 10 comprising a fuse state indicator 12 displaying a short circuit open fuse state 34. The short circuit open fuse state 34 is indicated on the thermographic paper 20 as a thicker wire line comprising intersecting wavy lines.

4

FIG. 3D is a top view of a fuse 10 comprising a fuse state indicator 12 displaying a thermal stress and/or open fuse state. The thermal stress and/or open fuse state 36 is indicated on the thermographic paper 20 as a black mark.

Although the exemplary embodiment described above has illustrated that certain markings have corresponding fuse state meanings, the same or similar marking may be given a different fuse state meaning in alternative embodiments without departing from the scope and spirit of the exemplary embodiment.

In an exemplary embodiment, the 80% current fuse tube temperatures may range from about 35° C. to about 65° C. depending upon the location of the measurement. Additionally, the 500% overload fuse tube temperatures may range from about 45° C. to about 90° C. depending upon the location of the measurement. However, at a particular location, the temperatures may be more consistent. It should be understood that these ranges may differ among different fuse types, classes and ratings without departing from the scope and spirit of the exemplary embodiment.

FIGS. 4A-4F illustrate photographic views of a temperature sensitive element displaying various fuse states in accordance with an exemplary embodiment. These photographic views were taken during an experiment on a GT3-FRS-R-30 fuse, which is manufactured by Cooper Bussmann, Inc. FIG. 4A is a photographic view of a temperature sensitive element displaying a good fuse state 40. FIG. 4B is a photographic view of a temperature sensitive element displaying a 200% overload fuse state 42. FIG. 4C is a photographic view of a temperature sensitive element displaying a 1200 A overload fuse state 44. FIG. 4D is a photographic view of a temperature sensitive element displaying a 2400 A short circuit fuse state 46. FIG. 4E is a photographic view of a temperature sensitive element displaying a 10 KA short circuit fuse state 48. FIG. 4F is a photographic view of a temperature sensitive element displaying a 100 KA short circuit fuse state 49. FIGS. 4A-4F illustrate the various responses of the temperature sensitive element 20 to the heat generated by the wire 17, which is positioned underneath the temperature sensitive element 20. As the amperage flowing across the wire 17 increases, the heat generated from the wire 17 also increases. Consequently, the increased heat causes the markings on the temperature sensitive element 20 to become more pronounced. Although this embodiment has the wire located underneath the temperature sensitive element, alternative embodiments may have the wire located on top of the temperature sensitive element without departing from the scope and spirit of the exemplary embodiment.

In an alternative embodiment, the temperature sensitive element 20 of the fuse state indicator 12 may comprise at least one material selected from a group consisting of thermochromic ink, thermochromic paint, thermal paper, liquid crystal polymers, thermal calibrated wax, nitrocellulose, and any substance that may be consumed and or out gas upon exposure to high temperatures, which are all capable of indicating a fuse state upon exposure to a particular temperature range.

Thermochromic inks or dyes are temperature sensitive compounds that temporarily change color with exposure to heat. When using the thermochromic inks or dyes, the color of the ink may change when exposed to the heat generated from the fuse 10 and/or the wire 17 while the fuse 10 is operating. The wire 17 is designed to disintegrate when the fuse 10 experiences a short circuit or a harmful overload condition and may then stop generating heat. Therefore, when the fuse 10 is not operating, either due to an open fuse, a fuse that has been installed improperly or an open circuit, the color of the

ink may be its original color. This color change may be reversible and may allow an operator to easily diagnose the state of the fuse 10.

Thermochromic paints are temperature sensitive pigments that temporarily change color with exposure to heat—After 5 absorbing a certain amount of light or heat, the crystalline or molecular structure of the pigment reversibly changes in such a way that it absorbs and emits light at a different wavelength than at lower temperatures. When using the thermochromic paints, the color of the paint may change when exposed to the heat generated from the fuse 10 and/or the wire 17 while the fuse 10 is operating. The wire 17 is designed to disintegrate when the fuse 10 experiences a short circuit or a harmful 10 overload condition and may then stop generating heat. Therefore, when the fuse 10 is not operating, either due to an open fuse, a fuse that has been installed improperly or an open circuit, the color of the paint may be its original color. This color change may be reversible and may allow an operator to easily diagnose the state of the fuse 10. 15

Thermal papers comprise one or more temperature sensitive chemicals that change color with exposure to heat. One 20 example of a thermal paper includes paper impregnated with a solid mixture of a fluoran dye with octadecylphosphonic acid. This mixture is stable in solid phase. However, when the octadecylphosphonic acid is melted, the dye undergoes chemical reaction in the liquid phase, and assumes the protonated colored form. Since this color change may not be reversible, the thermal paper may be used to indicate a short circuit or an overload. There may be some color change 30 during normal operation, but the intensity of the color change may increase as the temperature rises into the temperature range associated with a short circuit or an overload. In one embodiment, the thermal paper has a transition temperature between about 100° C. to about 120° C. It should be understood, however, that alternative thermal papers may be used 35 having different transition temperatures without departing from the scope and spirit of the exemplary embodiment.

FIG. 5 is a plan view of a fuse 50 comprising a fuse state indicator 52 that responds to voltage in accordance with an exemplary embodiment. The fuse 50 includes an insulative (i.e., nonconductive) fuse body 54 and conductive ferrules 56 40 attached thereto on either end thereof. The fuse state indicator 52 extends on an outer surface 58 of the fuse body 54 between the ferrules 56 and is electrically connected to the ferrules 56 by a wire 57. The fuse body 54 is elongated in the direction of a longitudinal axis 59 and is generally cylindrical in the illustrated embodiment. It is appreciated that the benefits of the instant invention may also apply to non-cylindrical fuses, including but not limited to rectangular fuses, in alternative 45 embodiments. Further, it is understood that the invention is applicable to a wide variety of fuses intended for a wide variety of applications and having a wide variety of fuse ratings. Therefore, the embodiments of the invention shown and described herein are for illustrative purposes only, and the invention is not intended to be restricted to a particular fuse type, class or rating. 50

In an exemplary embodiment, the ferrules 56 are generally cylindrical and complementary in shape to the fuse body 54. It is, however, appreciated that the benefits of the instant invention may also apply to non-cylindrical ferrules, including but not limited to rectangular ferrules, in alternative 60 embodiments.

The fuse state indicator 52 comprises at least one voltage sensitive element 60 capable of undergoing a visible change upon being subjected to a voltage. The voltage sensitive element 60 is adapted to visibly indicate the state of fuse 50. The state of fuse 50 may be indicated as operable or inoperable. 65

The voltage sensitive element 60 may be employed as part of the fuse state indicator 52 coupled to the outer surface 58 of the fuse 50 or the voltage sensitive element 60 may be employed independently. The voltage sensitive element 60 is 5 coupled to the outer surface 58 of the fuse body 54 between the ferrules 56 and is electrically connected to the ferrules 56 by the wire 57. The voltage sensitive element 60 may indicate a change in the state of the fuse 50 upon exposure to voltage. The voltage sensitive element 60 may also indicate a change 10 in the state of the fuse 50 upon exposure to heat which may or may not be caused by resistive heating of the wire 17. The wire 57 is designed so that it melts or becomes disconnected once a short circuit or a harmful overload condition occurs. In one embodiment, the wire 57 comprises a NiChrome alloy that melts above 1000° C. It should be understood that the wire may be constructed of other materials capable of melting, when exposed to a harmful overload condition, without 15 departing from the scope and spirit of the exemplary embodiment.

FIG. 6 is a cross sectional view of a fuse state indicator 52 in accordance with an exemplary embodiment. In this embodiment, the fuse state indicator 52 comprises a voltage sensitive element 60, a wire 57 electrically coupling the ferrules 56 (FIG. 5) to the voltage sensitive element 60, and at least one foil 64 coupled to the wire 57. The fuse state indicator 52 may further comprise a label 65 positioned adjacent 20 to the voltage sensitive element 60, wherein the label 65 has a window 66 defined therewithin. The window 66 may be positioned above the voltage sensitive element 60 such that the voltage sensitive element 60 is visible through the window 66. 25

The foil 64 is designed to protect an operator from exposure to excessive temperatures from the wire 57 while handling fuse 50. The foil 64 is designed to insulate the temperature from being too hot when an operator handles the fuse 50. The foil 64 may comprise any material capable of insulating the heat, including, but not limited to, copper foil or any thick film, without departing from the scope and spirit of the exemplary 30 embodiment.

Referring now to FIGS. 7A and 7B, the voltage sensitive element 60 is illustrated and its operation is described hereinbelow in accordance with an exemplary embodiment. In this embodiment, the voltage sensitive element 60 comprises a smart window 70. FIG. 7A is a perspective view of a smart window 70 showing the orientation of a plurality of polymer dispersed liquid crystals 71 when there is no voltage flowing across the smart window 70 in accordance with an exemplary 35 embodiment. FIG. 7B is a perspective view of a smart window 70 showing the orientation of a plurality of polymer dispersed liquid crystals 71 when there is voltage flowing across the smart window 70 in accordance with an exemplary embodiment. 40

As illustrated in these figures, the smart window 70 comprises a transparent lens 72, a first interlayer film 73 adjacent to the transparent lens 72, a first liquid crystal film 74 adjacent to the first interlayer film 73, a first conductive coating 75 adjacent to the first liquid crystal film 74, a plurality of polymer dispersed liquid crystals 71 adjacent to the first conductive coating 75, a second conductive coating 76 adjacent to the plurality of polymer dispersed liquid crystals 71, a second liquid crystal film 77 adjacent to the second conductive coating 76, a second interlayer film 78 adjacent to the second liquid crystal film 77 and a backing layer 79 adjacent to the second interlayer film 78. 45

These polymer dispersed liquid crystals 71 are liquid crystals capable of changing its orientation from a first orientation 68, wherein a substantial portion of the light does not pass 50

through the layer of polymer dispersed liquid crystals **71**, to a second orientation **69**, wherein a substantial portion of the light passes through the layer of polymer dispersed liquid crystals **71**. The polymer dispersed liquid crystals **71** are positioned in the first orientation **68** when an electrical charge is absent, which results when the fuse is in an inoperable state. Thus, when the fuse is in an inoperable state, the polymer dispersed liquid crystals **71** may be opaque thereby preventing the operator from viewing the backing layer **79**. However, the polymer dispersed liquid crystals **71** are positioned in the second orientation **69**, positioned parallel to one another, when an electrical charge is present, which results when the fuse is in an operable state. Thus, when the fuse is in an operable state, the polymer dispersed liquid crystals **71** may be translucent thereby allowing the operator to view the backing layer **79**. Hence, when using polymer dispersed liquid crystals **71**, the polymer dispersed liquid crystals **71** are either opaque (fuse is in an inoperable state) or translucent (fuse is in an operable state).

The electrical charge does not flow through the wire **57**, which is electrically connected to the smart window **70**, when the fuse is inoperable, which may result from an improperly installed fuse, an off circuit, or a fuse wherein the wire **57** may be melted or broken off due to a short circuit or an overcurrent. The electrical charge flows through the wire **57**, which is electrically connected to the smart window **70**, when the fuse is operable.

Although the embodiment described above illustrates that an electrical charge does not flow through the wire **57** when the fuse is inoperable, while an electrical charge flows through the wire **57** when the fuse is operable, the fuse and wire **57** may be designed such that the reverse occurs without departing from the scope and spirit of the exemplary embodiment. Specifically, the fuse and wire **57** may be designed so that an electrical charge flows through the wire **57** when the fuse is inoperable, while an electrical charge does not flow through the wire **57** when the fuse is operable.

Referring now to FIGS. **8A** and **8B**, another embodiment of the voltage sensitive element **60** is illustrated and its operation is described hereinbelow. In this embodiment, the voltage sensitive element **60** comprises a smart window **80**. FIG. **8A** is a perspective view of a smart window **80** showing the orientation of a plurality of suspended particle devices **81** when there is no voltage flowing across the smart window **80** in accordance with an exemplary embodiment. FIG. **8B** is a perspective view of a smart window **80** showing the orientation of a plurality of suspended particle devices **81** when there is voltage flowing across the smart window **80** in accordance with an exemplary embodiment.

As illustrated in these figures, the smart window **80** comprises a transparent lens **82**, a first conductive coating **84** adjacent to the transparent lens **82**, a plurality of suspended particle devices **81** adjacent to the first conductive coating **84**, a second conductive coating **86** adjacent to the plurality of suspended particle devices **81**, and a backing layer **88** adjacent to the second conductive coating **86**.

These suspended particle devices **81** are capable of changing orientation from a first orientation **87**, wherein a substantial portion of the light does not pass through the layer of suspended particle devices **81**, to a second orientation **89**, wherein a substantial portion of the light passes through the layer of suspended particle devices **81**. The suspended particle devices **81** are positioned in the first orientation **87** when an electrical charge is absent, which results when the fuse is in an inoperable state. Thus, when the fuse is in an inoperable state, the suspended particle devices **81** may be opaque thereby preventing the operator from viewing the backing

layer **88**. However, the suspended particle devices **81** are positioned in the second orientation **89**, positioned in alignment with one another, when an electrical charge is present, which results when the fuse is in an operable state. Thus, when the fuse is in an operable state, the suspended particle device **81** may be translucent thereby allowing the operator to view the backing layer **88**. Hence, when using suspended particle devices **81**, the suspended particle devices **81** are either opaque (fuse is in an inoperable state) or translucent (fuse is in an operable state).

The electrical charge does not flow through the wire **57**, which is electrically connected to the smart window **80**, when the fuse is inoperable, which may result from an improperly installed fuse, an off circuit, or a fuse wherein the wire **57** may be melted or broken off due to a short circuit or an overcurrent. The electrical charge flows through the wire **57**, which is electrically connected to the smart window **80**, when the fuse is operable.

Although the embodiment described above illustrates that an electrical charge does not flow through the wire **57** when the fuse is inoperable, while an electrical charge flows through the wire **57** when the fuse is operable, the fuse and wire **57** may be designed such that the reverse occurs without departing from the scope and spirit of the exemplary embodiment. Specifically, the fuse and wire **57** may be designed so that an electrical charge flows through the wire **57** when the fuse is inoperable, while an electrical charge does not flow through the wire **57** when the fuse is operable.

Referring now to FIGS. **9** and **10**, the various states of the fuse **50** are illustrated. In the embodiment shown in FIGS. **9** and **10**, a fuse state indicator **52** comprising at least one smart window **70**, **80** is illustrated.

In this embodiment, the smart window **70**, **80** may further comprise a first marking **100** coupled to the backing layer **79**, **68**, wherein the first marking **100** indicates that the fuse **50** is operable. Although this embodiment uses the word "on" as the first marking **100**, any marking may be used, including a particular color, e.g. green dot or square, or any other marking associated with an operable status, without departing from the scope and spirit of the exemplary embodiment. The first marking **100** may be marked on the surface of the backing layer **79**, **88** or may be marked on a material directly or indirectly coupled to the backing layer **79**, **88**.

FIG. **9** is a top view of a fuse **50** comprising a fuse state indicator **52** displaying an inoperable fuse state **90** in accordance with an exemplary embodiment. When the smart window **70** has no voltage passing through it, the polymer dispersed liquid crystals **71** orient to the first position, which is when the molecules point in a random manner and prevent the operator from viewing the first marking **100**. Similarly, in the alternative embodiment, when the smart window **80** has no voltage passing through it, the suspended particle devices **81** orient to the first position, which is when the molecules point in a random manner and prevent the operator from viewing the first marking **100**. When the fuse **50** is in the inoperable fuse state **90**, the polymer dispersed liquid crystals **71** and the suspended particle devices **81** both become opaque,

FIG. **10** is a top view of a fuse **50** comprising a fuse state indicator **52** displaying an operable fuse state **105** in accordance with an exemplary embodiment. When the smart window **70** has voltage passing through it, the polymer dispersed liquid crystals **71** orient to the second position, which is when the molecules point in mostly the same direction and allow the operator to view the first marking **100**. Similarly, in the alternative embodiment, when the smart window **80** has voltage passing through it, the suspended particle devices **81** orient to the second position, which is when the molecules

line up and allow the operator to view the first marking **100**. When the fuse **50** is in the operable fuse state **105**, the polymer dispersed liquid crystals **71** and the suspended particle devices **81** both become translucent.

Although the embodiment described above illustrates that an electrical charge does not flow through the wire **57** when the fuse is inoperable, while an electrical charge flows through the wire **57** when the fuse is operable, the fuse and wire **57** may be designed such that the reverse occurs without departing from the scope and spirit of the exemplary embodiment. Specifically, the fuse and wire **57** may be designed so that an electrical charge flows through the wire **57** when the fuse is inoperable, while an electrical charge does not flow through the wire **57** when the fuse is operable.

Referring now to FIGS. **11A** and **11B**, another embodiment of the voltage sensitive element **60** is illustrated and its operation is described hereinbelow. In this embodiment, the voltage sensitive element **60** comprises a smart window **110**. FIG. **11A** is a perspective view of a smart window **110** showing the positioning of a plurality of ions **111** when there is no voltage flowing across the smart window **110** in accordance with an exemplary embodiment. FIG. **11B** is a perspective view of a smart window **110** showing the positioning of a plurality of ions **111** when there is voltage flowing across the smart window **110** in accordance with an exemplary embodiment.

As illustrated in these figures, the smart window **110** comprises a transparent lens **112**, a first conductor **113** adjacent to the transparent lens **112**, an ion storage layer **114** adjacent to the first conductor **113**, an ion conductor/electrolyte layer **115** adjacent to the ion storage layer **114**, an electrochromic layer **116** adjacent to the ion conductor/electrolyte layer **115**, a second conductor **117** adjacent to the electrochromic layer **116**, a backing layer **118** adjacent to the second conductor **117**, and a plurality of ions **111** capable of moving between the ion storage layer **114** and the second conductor **117**.

These smart windows **110** center around special materials that have electrochromic properties. "Electrochromic" describes materials that can change color when energized by an electrical current. Essentially, electricity initiates a chemical reaction in this sort of material. The reaction changes the way the material reflects and absorbs light. In this embodiment, the changes between color comprise opaque and translucent, wherein the opaque color corresponds to a first fuse state (operable fuse state) and a translucent color corresponds to a second fuse state (inoperable fuse state). Although this embodiment utilizes opaque and translucent colors, other colors maybe used without departing from the scope and spirit of the exemplary embodiment. Additionally, there may be a color gradient from opaque and translucent without departing from the scope and spirit of the exemplary embodiment.

In this design, the chemical reaction involved comprises an oxidation reaction, wherein molecules of a compound lose an electron. As shown in FIG. **11A**, when there is no applied voltage to the smart window **110**, the plurality of ions **111** are positioned within the ion storage layer **114**, which results when the fuse is in an inoperable state. This positioning of the plurality of ions **111** allows light to pass through to the backing layer **118**. Thus, the smart window **110** becomes translucent and allows the operator to view the backing layer **118**. When voltage is applied to the smart window **110**, as illustrated in FIG. **11B**, the voltage drives the plurality of ions **111** from the ion storage layer **114** through the ion conductor/electrolyte layer **115** and into the electrochromic layer **116**, which results when the fuse is in an operable state. This positioning of the plurality of ions **111** prevents light from

passing through to the backing layer **118**. Thus, the smart window **110** becomes opaque and prevents the operator from viewing the backing layer **118**.

The electrical charge does not flow through the wire **57**, which is electrically connected to the smart window **110**, when the fuse is inoperable, which may result from an improperly installed fuse, an off circuit, or a fuse wherein the wire **57** may be melted or broken off due to a short circuit or an overcurrent. The electrical charge flows through the wire **57**, which is electrically connected to the smart window **110**, when the fuse is operable.

Although the embodiment described above illustrates that an electrical charge does not flow through the wire **57** when the fuse is inoperable, while an electrical charge flows through the wire **57** when the fuse is operable, the fuse and wire **57** may be designed such that the reverse occurs without departing from the scope and spirit of the exemplary embodiment. Specifically, the fuse and wire **57** may be designed so that an electrical charge flows through the wire **57** when the fuse is inoperable, while an electrical charge does not flow through the wire **57** when the fuse is operable.

Referring now to FIGS. **12** and **13**, the various states of the fuse **50** are illustrated. In the embodiment shown in FIGS. **12** and **13**, a fuse state indicator **52** comprising at least one smart window **110** is illustrated.

In this embodiment, the smart window **110** may further comprise an alternative marking **120** coupled to the backing layer **118**, wherein the alternative marking **120** indicates that the fuse **50** is inoperable. Although this embodiment uses the word "off" as the alternative marking **120**, any marking may be used, including a particular color, e.g. black dot or square, or any other marking associated with an inoperable status, without departing from the scope and spirit of the exemplary embodiment. The alternative marking **120** may be marked on the surface of the backing layer **118** or may be marked on a material directly or indirectly coupled to the backing layer **118**.

FIG. **12** is a top view of a fuse **50** comprising a fuse state indicator **52** displaying an inoperable fuse state **122** in accordance with an exemplary embodiment. When the smart window **110** has no voltage passing through it, the plurality of ions **111** are positioned within the ion storage layer **114**, which allows the operator to view the alternative marking **120**.

FIG. **13** is a top view of a fuse **50** comprising a fuse state indicator **52** displaying an operable fuse state **130** in accordance with an exemplary embodiment. When the smart window **110** has voltage passing through it, the plurality of ions **111** become mostly positioned within the electrochromic layer **116**, which prevents the operator from viewing the alternative marking **120**.

With respect to all the embodiments described, the fuse state indicator **52** may comprise lettering to describe the fuse **50** and the fuse states. The fuse state indicator **52** may also comprise a color chart for assisting a user in identifying the meaning of the color change. To further assist operators in analyzing the status of the fuse **50**, pocket cards comprising color charts may be provided to the operators.

Additionally, although the exemplary embodiments described above illustrate the fuse **50** comprising one voltage or temperature sensitive element, multiple voltage or temperature sensitive elements may be utilized without departing from the scope and spirit of the exemplary embodiment.

Furthermore, although some exemplary embodiments have been described above, it is envisioned that the various voltage and temperature sensitive elements that have been described may be used alternatively in lieu of one another or

in combination with each other without departing from the scope and spirit of the invention.

Although the invention has been described with reference to specific embodiments, these descriptions are not meant to be construed in a limiting sense. Various modifications of the disclosed embodiments, as well as alternative embodiments of the invention will become apparent to persons skilled in the art upon reference to the description of the invention. It should be appreciated by those skilled in the art that the conception and the specific embodiments disclosed may be readily utilized as a basis for modifying or designing other structures for carrying out the same purposes of the invention. It should also be realized by those skilled in the art that such equivalent constructions do not depart from the spirit and scope of the invention as set forth in the appended claims. It is therefore, contemplated that the claims will cover any such modifications or embodiments that fall within the scope of the invention.

What is claimed is:

1. A fuse comprising:
  - a fuse body having an exterior surface; electrical terminal elements coupled to the fuse body; and a fuse state indicator on the exterior surface of the fuse body, the fuse state indicator including:
    - an electrically conductive element electrically connected to and extending between the terminal elements and configured for resistive heating in an overcurrent condition; and
    - a temperature sensitive element proximate the electrically conductive element and in thermal contact therewith, wherein the temperature sensitive element comprises material capable of changing color when heated to a predetermined transition temperature to form a mark on the temperature sensitive element,
 wherein the fuse state indicator is configured to form a first mark on the temperature sensitive element due to heat transferring from the electrically conductive element to the temperature sensitive element in response to a first overcurrent condition, and is configured to form a second mark, distinct from the first mark, on the temperature sensitive element due to heat transferring from the electrically conductive element to the temperature sensitive element in response to a second overcurrent condition distinct from the first overcurrent condition, wherein the first mark comprises an image of the electrically conductive element, and the second mark comprises an image of the electrically conductive element and deviated marks that deviate from the image of the electrically conductive element.
  2. The fuse of claim 1, wherein the fuse state indicator is configured to form a third mark on the temperature sensitive element, different from the first and second marks, due to heat transferring from the electrically conductive element to the temperature sensitive element in response to a third overcurrent condition distinct from the first and second overcurrent conditions.
  3. The fuse of claim 1, wherein the fuse state indicator further includes a window, the electrically conductive element being disposed between the window and the at least one temperature sensitive element.
  4. The fuse of claim 1, wherein the temperature sensitive element comprises thermal paper.
  5. The fuse of claim 4, wherein the thermal paper has a transition temperature between about 100 degrees C. and about 120 degrees C.
  6. The fuse of claim 1, wherein the electrically conductive element comprises a wire.

7. The fuse of claim 6, wherein the wire melts about 1000 degrees C.

8. The fuse of claim 7, wherein the wire comprises a NiChrome alloy.

9. The fuse of claim 1, wherein the deviated marks extend laterally outward from the image of the electrically conductive element of the second mark.

10. The fuse of claim 1, wherein the terminal elements comprise ferrules.

11. A fuse comprising:
 

- a pair of spaced apart electrical terminal elements; an electrically conductive wire electrically connecting the electrical terminal elements and extending along a wire path, the electrically conductive wire being configured for resistive heating in an overcurrent condition;
- a temperature sensitive element adapted to change color when heated to a predetermined transition temperature, wherein the temperature sensitive element extends along at least a portion of the electrically conductive wire in thermal contact therewith and is adapted to absorb heat from the electrically conductive wire;

 wherein the temperature sensitive element is adapted to change color along a first conforming path that substantially conforms to the wire path of the electrically conductive wire in a first overcurrent condition; wherein the temperature sensitive element is adapted to change color at a combined second conforming path, which substantially conforms to the wire path of the electrically conductive wire, and at least one first deviating path, which deviates from the conforming path, in a second overcurrent condition that is distinct from the first overcurrent condition.

12. The fuse of claim 11, wherein the at least one first deviating path extends laterally outward from the second conforming path.

13. The fuse of claim 12, wherein the at least one first deviating path comprises a plurality of deviating paths spaced apart along the second conforming path.

14. The fuse of claim 13, wherein the temperature sensitive element is adapted to change color along a combined third conforming path that substantially conforms to the wire path of the electrically conductive wire and a plurality of second deviating paths that deviate from the conforming path in a third overcurrent condition distinct from the first and second overcurrent conditions, wherein lateral extents of the second deviating paths are greater than lateral extents of the second deviating paths.

15. The fuse of claim 11, wherein the first conforming path has a thickness that is less than a thickness of the second conforming path.

16. The fuse of claim 15, wherein the at least one first deviating path comprises a plurality of wavy lines that intersect the second conforming path.

17. The fuse of claim 14, wherein the first conforming path indicates an overload fuse state, and wherein the combined second conforming path and the at least one first deviating path indicates a short circuit fuse state.

18. The fuse of claim 11, wherein the pair of spaced apart electrical terminal elements comprises a pair of ferrules.

19. The fuse of claim 11, wherein the temperature sensitive element comprises thermal paper.

20. The fuse of claim 11, wherein the electrically conductive wire comprises a NiChrome alloy.

21. A fuse comprising:
 

- a fuse body having an exterior surface;
- a pair of spaced apart electrical terminal elements on the fuse body; and

## 13

a fuse state indicator on the exterior surface of the fuse body, the fuse state indicator including:

a temperature sensitive element having an upper surface facing away from the exterior surface of the fuse body, the temperature sensitive element comprising a material that is capable of changing color when heated to a predetermined transition temperature to form a mark on the temperature sensitive element,

an electrically conductive element extending across the upper surface of the temperature sensitive element in thermal contact therewith, the electrically conductive element electrically connecting the pair of spaced apart electrical terminal elements and being configured for resistive heating in an overcurrent condition, and

a window overlying at least a portion of the upper surface of the temperature sensitive element and at least a portion of the electrically conductive element,

wherein the fuse state indicator is configured to form an image of the electrically conductive element on the temperature sensitive element due to heat transferring from the electrically conductive element to the temperature sensitive element in response to an overcurrent condition.

**22.** The fuse of claim **21**, wherein the temperature sensitive element comprises thermal paper.

## 14

**23.** The fuse of claim **22**, wherein the predetermined transition temperature of the thermal paper is between about 100 degrees C. to about 120 degrees C.

**24.** The fuse of claim **21**, wherein the electrically conductive element comprises a wire.

**25.** The fuse of claim **24**, wherein the wire has a melting temperature above 1000 degrees C.

**26.** The fuse of claim **25**, wherein the wire comprises NiChrome alloy.

**27.** The fuse of claim **21**, further comprising a label defining the window therewithin.

**28.** The fuse of claim **24**, further comprising at least one foil coupled to the wire.

**29.** The fuse of claim **21**, wherein said at least a portion of the upper surface of the temperature sensitive element and said at least a portion of the electrically conductive element are visible through the window.

**30.** The fuse of claim **21**, wherein the fuse body has opposite longitudinal ends and a length extending therebetween, wherein the pair of spaced apart electrical terminal element are on the opposite longitudinal ends of the fuse body, the electrically conductive element extending longitudinally, with respect to the fuse body, across the upper surface of the temperature sensitive element.

\* \* \* \* \*